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14. ABSTRACT
Littoral hydrodynamic models are valuable tools for characterizing near shore waves and currents. There are a number of ways to prescribe boundary conditions for the model. A tide model is used to obtain astronomic boundary conditions, or among other sources, a regional model can provide time series boundary conditions. We investigate the differences imposed by these two types of boundary conditions for 4 model cases-two-and three-dimensional cases at two locations. Furthermore, we investigate how changing the temporal resolution of the time series boundary condition and how varying the horizontal resolution of the regional model affects the model results.

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An Evaluation of Boundary Condition Specification for a Littoral Hydrodynamic Model

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Abstract— **Littoral hydrodynamic models are valuable tools for characterizing near shore waves and currents. There are a number of ways to prescribe boundary conditions for the model. A tide model is used to obtain astronomic boundary conditions, or among other sources, a regional model can provide time series boundary conditions. We investigate the differences imposed by these two types of boundary conditions for 4 model cases—two- and three-dimensional cases at two locations. Furthermore, we investigate how changing the temporal resolution of the time series boundary condition and how varying the horizontal resolution of the regional model affects the model results.**

Nearshore; circulation; littoral; hydrodynamic; model; Delft3D

I. INTRODUCTION

Characterization and forecasts of the littoral environment are valuable sources of information for Navy missions including but not limited to ship to shore movement of supplies and personnel and deployment, operation, and retrieval of sensors. Numerical models provide estimates of dynamic littoral parameters like water levels, current speeds and directions, wave heights, and wave directions. More specifically, a hydrodynamic model provides the water level and current predictions. Boundary conditions for the hydrodynamic model are easily obtained from an inverse tide model. The investigations herein employ OSU Tides with the TPXO 7.2 model [1]. The tide model provides amplitudes and phases of water level for many tidal constituents, and the information can be given directly to the hydrodynamic model. Limitations imposed by the tide model include its resolution in coastal areas and inability to provide information in the vertical dimension. Furthermore, previous work showed that obtaining boundary conditions from the tide model may result in underestimated velocity magnitudes [2].

An alternative to obtaining boundary conditions from a tide model is obtaining them from a regional hydrodynamic model. For the studies herein, the regional model is the Navy Coastal Ocean Model (NCOM) [3]. Regional hydrodynamic models provide data to the littoral model boundaries as time series. The information can be interpolated in time and horizontal and vertical space. A subset of available options for littoral hydrodynamic model boundary conditions is investigated. The littoral model is Delft3D [4], [5]. First, we show model differences resulting from a change in boundary condition type—astronomic (OSU Tides) or time series (NCOM). Then we investigate how variations in the time series boundary condition may affect model results. The following section provides details on our model cases and tests. Section III describes our findings, and discussion and conclusions are given in Section IV.

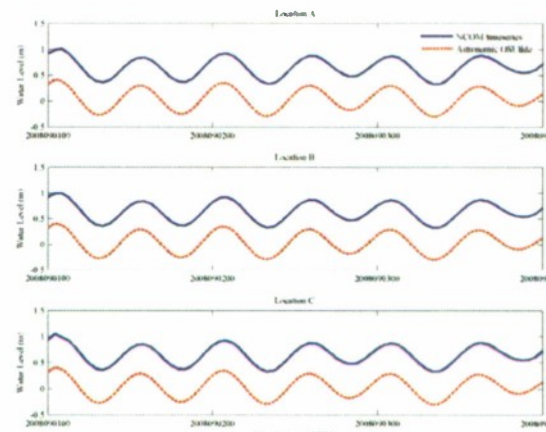

Figure 1. Water levels as predicted by Delft3D using astronomic boundary conditions from OSU Tides (red) and time series boundary conditions from NCOM (blue) for 3 locations in the M2D model case.

II. APPROACH

Several comparisons of Delft3D model results were completed for a number of model cases (described in the following subsection). These comparisons investigate differences in model output resulting from variations in flow boundary conditions. The comparisons include using a regional circulation model (NCOM) for Delft3D boundary conditions as opposed to using a tide model (OSU Tides). We further investigate the use of a regional model for boundary conditions by varying the temporal resolution of the calculated boundary condition and by varying the resolution of the regional model fields. Additional comparison details are given in section II.B.

A. Model Cases

All model cases are initialized from the boundary condition source—either OSU Tides or a regional NCOM model. In both cases the regional NCOM model provides output in 3 hour increments.

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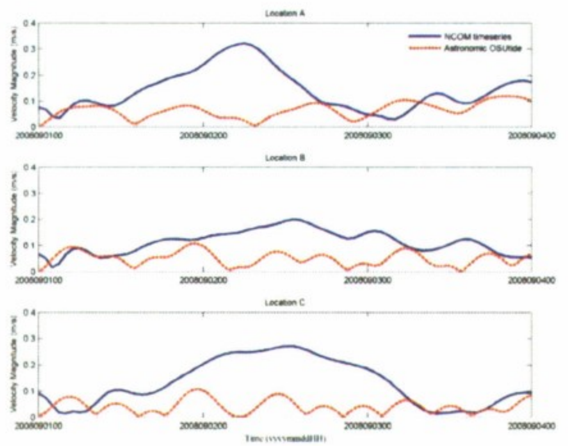

Figure 2. Velocity magnitudes as predicted by Delft3D using astronomic boundary conditions from OSU Tides (red) and time series boundary conditions from NCOM (blue) for 3 locations in the M2D model case.

1) M2D and M3D

The M2D and M3D Delft3D applications cover approximately 33 square kilometers at a resolution of approximately 500 meters. The M2D model case is depth averaged; the M3D model case contains 20 vertical sigma layers. The M3D application includes temperature and salinity. The regional NCOM available for time series boundary condition file generation provided information at a horizontal scale of 3 kilometers. The Delft3D application predicted model fields for a 72 hour period beginning 01 September 2008.

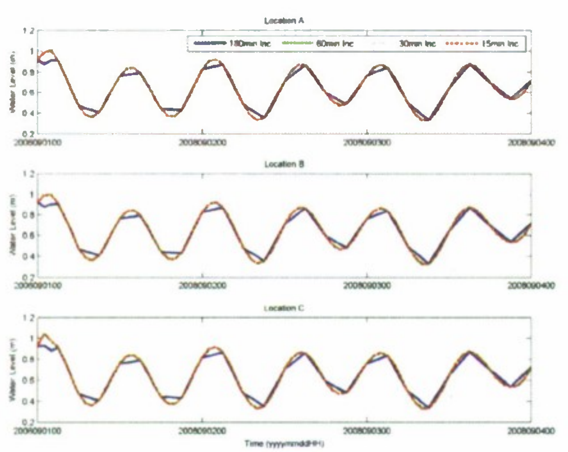

Figure 3. Water levels predicted by Delft3D for the M2D model case using time series boundary conditions from NCOM, where the boundary condition is specified at varying temporal resolution—180 minutes (blue), 60 minutes (green), 30 minutes (black), 15 minutes (red).

2) J2D and J3D

The J2D and J3D Delft3D applications use an irregular grid. The longest extent North to South is approximately 280 kilometers and East to West is approximately 87 kilometers. The resolution varies from scales as small as 500 meters to scales as large as 10 kilometers. The J2D model case is depth averaged; the J3D model case contains 10 vertical sigma layers. Like the M3D application, J3D includes temperature and salinity. A regional NCOM with a horizontal scale of 1 kilometer was available for time series boundary condition file generation. The Delft3D application provided results spanning 04 April to 08 April 2011.

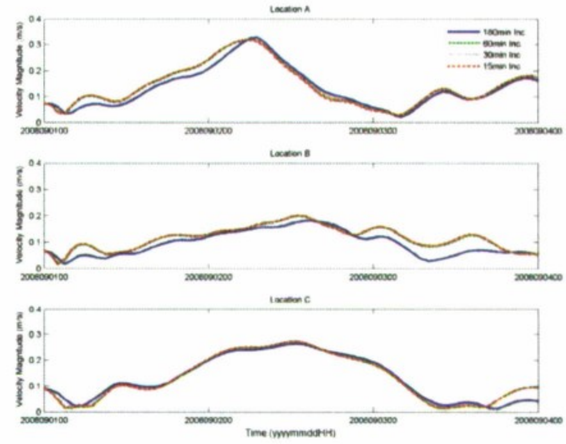

Figure 4. Velocity magnitudes predicted by Delft3D for the M2D model case using time series boundary conditions from NCOM, where the boundary condition is specified at varying temporal resolution—180 minutes (blue), 60 minutes (green), 30 minutes (black), 15 minutes (red).

B. Tests

1) Boundary Condition Type

The effects of boundary condition type were investigated for the M2D and J2D model cases. Each model case was executed once using an astronomic boundary condition file obtained from OSU Tides and once using a time series boundary condition file obtained from a regional NCOM model.

2) Time Series Temporal Resolution

The importance of the temporal resolution of the time series boundary condition file was investigated for all four model cases. This was accomplished by interpolating the 3 hour regional NCOM model output to varying time increments. Time series boundary condition files were generated for each model case using time intervals of 3 and 1 hour and 30 and 15 minutes.

3) Regional Model Horizontal Resolution

The effects of varying the horizontal resolution of the regional NCOM model were considered using the J2D and J3D model cases. For these two cases, 1 kilometer NCOM model results were subsampled to 3 kilometers before time series boundary condition files were generated for the model cases.

III. Results

A comparison of water levels resulting from the test of boundary condition type shows approximately a 0.5 meter difference for the M2D model case. Although the amplitudes differ, the results are in phase. Figure 1 shows the differences for three points in the model domain. In addition to differences in water level, the boundary condition test for model case M2D

resulted in differences in velocity magnitude. A representation of these differences is shown in Figure 2. For the three locations chosen for a time series comparison, the velocity magnitude differs by as much as 0.3 meters/second.

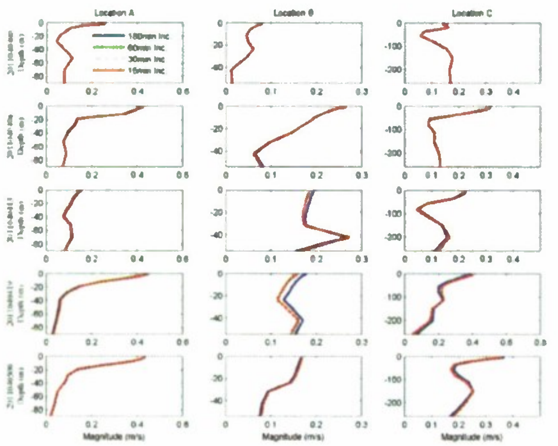

Figure 5. Velocity Magnitude profiles predicted by Delft3D for the J3D model case using time series boundary conditions from NCOM, where the boundary condition is specified with varying temporal resolution—180 minutes (blue), 60 minutes (green), 30 minutes (black), 15 minutes (red).

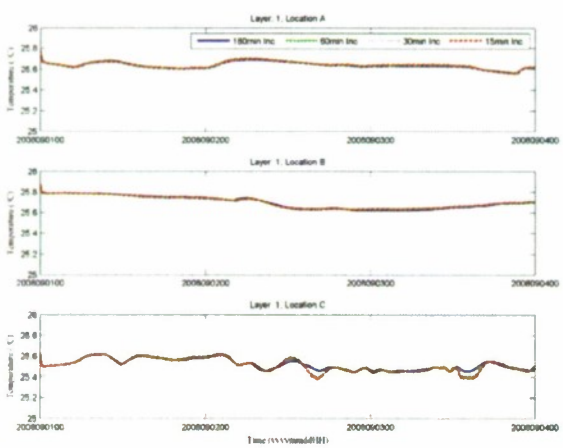

Figure 6. Temperature at the surface layer predicted by Delft3D for the M3D model case using time series boundary conditions from NCOM, where the boundary condition is specified at varying temporal resolution—180 minutes (blue), 60 minutes (green), 30 minutes (black), 15 minutes (red).

From comparisons of water levels resulting from testing the importance of time series temporal resolution for the M2D model case, we see that some interpolation is required of the 3 hour NCOM fields. Figure 3 shows that by interpolating the 3 hour NCOM results to a time frame with a 1 hour increment affects the Delft3D model results. If the 3 hour increment is used, some of the water level high- and low- water marks are missed. Slight differences in velocity magnitudes are seen in the time series of the three comparison locations (Figure 4), but differences resulting from variations in the time series temporal resolution are much less pronounced than the differences caused by the varying boundary condition type. The M3D and J3D model test cases resulted in similar comparisons of water level and velocity magnitude for the time series temporal resolution test with minor differences in velocity magnitude profiles detected (Figure 5). Furthermore, even smaller to no differences were seen in the salinity and temperature fields of the M3D and J3D model cases, with the largest of the differences occurring at M3D's comparison point C (Figure 6).

The J2D and J3D model cases were used to investigate the importance of the regional model horizontal resolution. Comparisons of Delft3D results using a 1 kilometer NCOM data set and a representative 3 kilometer NCOM data set show no differences in water level for both the two- and three-dimensional model cases. Furthermore, J2D shows little change in velocity magnitudes with respect to a change in the horizontal resolution of the supporting regional NCOM model. In the three-dimensional model case, however, the differences in Delft3D predicted velocity magnitudes with respect to the horizontal resolution of the supporting regional model increase as the simulation time increase. This observation is pronounced at comparison location A, as shown in the vertical profiles displayed in Figure 7. In the 74^{th} hour of the simulation (2011040702), the difference at the surface is approximately two-fold. Comparisons of profiles at locations B and C indicate a similar response to a change in the horizontal resolution of the supporting regional model. As the simulation time increases, the difference in velocity magnitude increases.

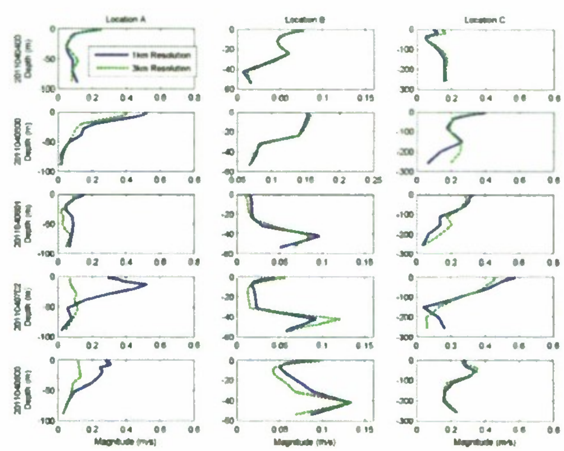

Figure 7. Velocity magnitude as predicted by Delft3D for the J3D model case using time series boundary conditions from NCOM, where NCOM's horizontal resolution was 1 kilometer (blue) and subsampled at 3 kilometers (green).

IV. Discussion

When regional model results are used to generate boundary conditions, they are used to initialize Delft3D water levels and velocities. When astronomic boundary conditions are used, only water levels are considered; velocities are not initialized. It is possible that the difference in water levels is caused by a difference in vertical reference for the two boundary condition sources (OSU Tides and NCOM), but further investigation is required to verify. An additional possible cause of the

difference in velocity magnitudes is that the tide model accounts for only tidal flow; the regional NCOM includes additional flow like boundary currents. Furthermore, NCOM includes assimilation of available oceanographic data.

It does not appear that the temporal resolution of the time series boundary condition needs to be resolved to anything less than an hour. The choice of boundary condition type is more important than the resolution of the time series.

The representative 3 kilometer NCOM is the same data set as the 1 kilometer NCOM; it is just fewer points. For the two-dimensional model parameter water level, we see no difference in the Delft3D predictions for the horizontal resolution test. However, for the three-dimensional test case, differences in the Delft3D results occur because of a change in the horizontal resolution of the supporting NCOM model. Therefore, the horizontal resolution of the supporting regional model does not appear to be as important a factor for the two-dimensional models as it is for the three-dimensional models, but further tests are required to make a more sound judgment. A better test requires independent NCOM models with varying resolution—perhaps the host of the 1 kilometer NCOM would suffice, but additional effort is required. Furthermore, the model test case resolution is nearly the same as the NCOM resolution; a higher resolution model test case will be investigated in the near future.

Repeating the included tests for a Delft3D test case with corresponding data will allow for a more quantitative analyses of how the boundary condition type, boundary condition temporal resolution and supporting model horizontal resolution affect the Delft3D results.

From the three tests performed, we conclude that using the regional model for boundary conditions, regardless of its temporal resolution, is better than using the tide model. Although, in a pinch, the tide model can be used for 2 dimensional, depth averaged simulations.

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